IN THE SPECIFICATION

Please amend the paragraphs below as follows:

[0001] - - This invention relates to ~~methods of manufacture of~~ trench optical devices formed in semiconductor substrates ~~and structures produced thereby~~, and more particularly to ~~methods of manufacture of~~ one or more trench lateral p-i-n photodiodes alone or in an array in a photodetector ~~and structures produced thereby~~.

[0014] First Prior Art Process

1. Start with a semiconductor type of substrate with a planar surface.

[0015] 2. Form a pad layer atop the semiconductor substrate and form a first hardmask layer atop the pad layer. As indicated above, in the final device, light passes through the pad layer 14 into the intrinsic region 11 generating holes "h^+" and electrons "e^-".

[0035] Second Prior Art Process

1. Start with a semiconductor or SOI type of substrate with a planar surface.

[0036] 2. Form a pad layer atop the semiconductor substrate and form a first hardmask layer atop the pad layer. As indicated above, in the final device, light passes through the pad layer 14 into the intrinsic region 11 generating holes "h^+" and electrons "e^-".

[0061] In accordance with this invention, a semiconductor device is formed in a semiconductor substrate. ~~Start by forming a~~ A wide trench and a narrow trench are formed in the substrate. ~~Then form a~~ A first electrode in the narrow trench ~~by depositing~~ comprises a first fill material of a first conductivity type. ~~over the device to fill the wide trench partially and to fill the narrow trench completely.~~ ~~Then etch back the first fill material until completion of removal thereof from the wide trench.~~ ~~Form a~~ A second electrode in the wide trench ~~by filling~~ fills the wide trench with a second fill material of an opposite conductivity type. ~~Anneal to drive dopant~~ Dopant diffused from the first fill material of the first electrode [[into]] forms a first outdiffusion region in the substrate about the periphery of the narrow trench. [[,]] Dopant diffused ~~and to drive dopant~~ from the second fill material of the second electrode [[into]] forms a second outdiffusion region in the substrate about the periphery of the wide trench.

[0062] ~~Preferably, only a single set of masks is employed to produce the device including only one layer of resist and only one hardmask layer.~~ Preferably, a liner is deposited into the narrow trench and the wide trench prior to deposition of the first fill material. Preferably, [[form]] a contact is formed to the first electrode and ~~forming~~ a contact is formed to the second electrode. Preferably, [[form]] a cap layer was formed over the device prior to annealing. Preferably, the material of the first conductivity type comprises N-type doped polysilicon and the material of the second conductivity comprises P-type doped polysilicon. Preferably, the material of the first fill material comprises N-type doped polysilicon and the material of the second fill material comprises P-type doped polysilicon. Preferably, the semiconductor substrate is formed over a buried oxide layer. Preferably, the semiconductor substrate is composed of a material selected from ~~as follows~~ the group consisting of: Si, strained Si, $Si_{1-y}C_y$, $Si_{1-x-y}Ge_xC_y$, $Si_{1-x}Ge_x$, Si alloys, Ge, Ge alloys, GaAs, InAs, InP as well as other III-V semiconductors, II-VI semiconductors, Si-containing materials, a Silicon-On-Insulator (SOI) substrates or a SiGe-On-Insulator (SGOI) substrates. Preferably, the liner material is composed of a material selected from ~~as follows~~ the group consisting of: silicon nitride, Ge, SiGe, WSix, TiN, Ta, Ti, and SiC.

[0063] ~~In accordance with another aspect of this invention a method of forming a photodetector device on a semiconductor substrate, comprises the following steps. Form a wide trench and a narrow trench in the substrate. Form a first electrode in the narrow trench by depositing with a first fill material of a first conductivity type over the device thick enough to fill the wide trench partially and filling the narrow trench completely and then etching back the first fill material until completion of removal thereof from the wide trench. Form an epitaxial semiconductor layer in the wide trench leaving a narrowed wide trench therein. Form a second electrode in the wide trench by filling the wide trench with second fill material of an opposite conductivity type. Anneal to drive dopant both from second electrode into a region in the substrate about the periphery of the wide trench and from the first electrode into a region in the substrate about the periphery of the narrow trench. Preferably, only a single set of masks is employed to produce the device including only one layer of resist and only one hardmask layer. Preferably, a second liner is deposited into the narrowed wide trench prior to deposition of the second fill material. Preferably, a liner is deposited into the narrow trench and the wide trench prior to deposition of the first fill material. Preferably, a second liner is deposited into the narrowed wide trench prior to deposition of the second fill material. Preferably, form a silicide contact to the first electrode and form a silicide contact to the second electrode.~~

[[0092] First Process Flow

FIG. 3 shows a first process flow for forming the photodetector 100 of FIGS. 2A-2C, which involves the steps as follows:

In step 50, the process begins.

[[0092] In step 51, as indicated by FIG. 4A, a semiconductor substrate 12 was provided covered with a blanket pad layer 14 (which may be laminated layers of silicon oxide and silicon nitride). Then as indicated above, with respect to the prior art devices in the final device, light which passes through the pad layer 14 into the intrinsic region 11 generates holes "h^+" and electrons "e^-". ~~which in turn~~ Then blanket pad layer 14 was covered by a blanket hardmask layer 15. Then an imaging layer 16, e.g., photoresist, was formed over the hardmask layer 15. The layers 15 and 16 are preferably planar in FIG. 4A.

[0099] In step 56, as shown in FIG. 4C, the remainder of the hardmask 15 has been stripped. ~~and an optional ultra-thin liner 20, has been formed on the exposed sidewalls and bottom of the trenches 17 and 18. The liner 20 prevents the defect formation in the later trench filling process. It also facilitates the later polysilicon etchback process.~~

[0100] An optional preliminary step is to form the ultra-thin, protective, conformal liner 20, preferably composed of silicon nitride on the exposed sidewalls and bottom of the trenches 17 and 18, beneath the first trench filling layer 126B. The optional ultra-thin liner 20, has been formed on the exposed sidewalls and bottom of the trenches 17 and 18. The liner 20 prevents the defect formation in the later trench filling process. It also facilitates the later polysilicon etchback process.

[0115] Optionally, a thin liner 20 may be formed on trench sidewalls and bottoms before the wide trench 17 and narrow trench 18 are filled with the conductive, first trench filling material 126B. This thin liner 20 will act as etch stopping layer when the first trench filling material 126B is removed from the wide trench 17, in the next step. It also prevents the formation of defects such as dislocations at the interface of a first trench filling material 126B such as polysilicon and a single-crystal silicon substrate 12, when a first trench filling material 126B such as polysilicon is used to fill the wide trench 17 and the narrow trench 18. Preferably the thin liner 20 is a thin layer of silicon nitride which is thin enough to allow electrons and holes to tunnel therethrough. The thickness of a silicon nitride liner 20 is preferably thinner than 15 angstroms (Å) and it is preferred to have a thickness between about 5Å and about 10Å. Preferably, the silicon nitride liner 20 is formed by thermal growth. Alternatively the thin silicon nitride liner 20 [[, it]] can be formed by deposition such as low-pressure CVD (LPCVD) or atomic layer deposition (ALD). Other materials, including but not limited to Ge, SiGe, WSix, TiN, Ta, Ti, or SiC, etc., may be used as the thin liner 20.

[0129] Second Embodiment

FIGS. 5A and 5B show sectional and plan views of a modified lateral trench, p-i-n diode photodetector manufactured by a modification of the process of FIGS. 2A-2B in accordance with this invention. FIG. 5A shows a sectional elevation taken along line 5A-5A in FIG. 5B of a single lateral trench p-i-n photodiode with a wide trench lined with epitaxial silicon. FIG. 5B shows an array of lateral trench p-i-n photodiodes connected in parallel taken along line 5B-5B in FIG. 5A.

[0145] SOI Embodiments

FIGS. 8A and 8B show sectional and plan views of a lateral trench, p-i-n diode photodetector manufactured by a modification of the process of FIGS. 2A-2C, 3 and 4G in accordance with this invention.

[0146] In FIG. 8A a photodetector device 100' is shown comprising a modification of the photodetector 100 of FIGS. 2A and 4G with the photodetector of FIG. 8A built on an SOI substrate 112 with a BOX layer 113 formed on the SOI substrate 112 and the photodetector substrate 12 formed on the BOX layer 113. Otherwise the process and the structure are the same as in FIGS. 4A-4GE. Please refer to [[US]] U.S. patent No. 6,538,299 of Kwark entitled "Silicon-On-Insulator (SOI) Trench Photodiode" cited above for a full description of the benefits of an SOI embodiment.

FIG. 8B shows a perspective view of the device 100' of FIG. 8A, which is analogous to similar views described hereinabove.